OpenCore

Reference Manual (0.5.3.4)

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Failsafe: `false`
Description: Reuse original hibernate memory map.

This option forces XNU kernel to ignore newly supplied memory map and assume that it did not change after waking from hibernation. This behaviour is required to work by Windows, which mandates to preserve runtime memory size and location after S4 wake.

Note: This ~~option is deprecated and will be removed in the newer OpenCore releases. There is no known hardwarethat needs this option, and its entire existence appears to be a programmer error. Please report on if you need this option~~may be used to workaround buggy memory maps on older hardware, and is now considered rare legacy. Examples of such hardware are Ivy Bridge laptops with Insyde firmware, like Acer V3-571G. Do not use this unless you fully understand the consequences.

6. `EnableSafeModeSlide`
Type: `plist boolean`
Failsafe: `false`
Description: Patch bootloader to have KASLR enabled in safe mode.

This option is relevant to the users that have issues booting to safe mode (e.g. by holding `shift` or using `-x` boot argument). By default safe mode forces `0` slide as if the system was launched with `slide=0` boot argument. This quirk tries to patch `boot.efi` to lift that limitation and let some other value (from `1` to `255`) be used. This quirk requires `ProvideCustomSlide` to be enabled.

Note: The necessity of this quirk is determined by safe mode availability. If booting to safe mode fails, this option can be tried to be enabled.

7. `EnableWriteUnprotector`
Type: `plist boolean`
Failsafe: `false`
Description: Permit write access to UEFI runtime services code.

This option bypasses `RX̂` permissions in code pages of UEFI runtime services by removing write protection (`WP`) bit from `CR0` register during their execution. This quirk requires `OC_FIRMWARE_RUNTIME` protocol implemented in `FwRuntimeServices.efi`.

Note: The necessity of this quirk is determined by early boot crashes of the firmware.

8. `ForceExitBootServices`
Type: `plist boolean`
Failsafe: `false`
Description: Retry `ExitBootServices` with new memory map on failure.

Try to ensure that `ExitBootServices` call succeeds even with outdated MemoryMap key argument by obtaining current memory map and retrying `ExitBootServices` call.

Note: The necessity of this quirk is determined by early boot crashes of the firmware. Do not use this unless you fully understand the consequences.

9. `ProtectCsmRegion`
Type: `plist boolean`
Failsafe: `false`
Description: Protect CSM region areas from relocation.

Ensure that CSM memory regions are marked as ACPI NVS to prevent boot.efi or XNU from relocating or using them.

Note: The necessity of this quirk is determined by artifacts and sleep wake issues. As `AvoidRuntimeDefrag` resolves a similar problem, no known firmwares should need this quirk. Do not use this unless you fully understand the consequences.

10. `ProvideCustomSlide`
Type: `plist boolean`
Failsafe: `false`
Description: Provide custom KASLR slide on low memory.

This option performs memory map analysis of your firmware and checks whether all slides (from `1` to `255`) can be used. As `boot.efi` generates this value randomly with `rdrand` or pseudo randomly `rdtsc`, there is a chance of boot failure when it chooses a conflicting slide. In case potential conflicts exist, this option forces macOS to use a pseudo random value among the available ones. This also ensures that `slide=` argument is never passed to the operating system for security reasons.

Note: The necessity of this quirk is determined by `OCABC: Only N/256 slide values are usable!` message in the debug log. If the message is present, this option is to be enabled.

11. `SetupVirtualMap`
Type: `plist boolean`
Failsafe: `false`
Description: Setup virtual memory at `SetVirtualAddresses`.

Select firmwares access memory by virtual addresses after `SetVirtualAddresses` call, which results in early boot crashes. This quirk workarounds the problem by performing early boot identity mapping of assigned virtual addresses to physical memory.

Note: The necessity of this quirk is determined by early boot failures.

12. `ShrinkMemoryMap`
Type: `plist boolean`
Failsafe: `false`
Description: Attempt to join similar memory map entries.

Select firmwares have very large memory maps, which do not fit Apple kernel, permitting up to `64` slots for runtime memory. This quirk attempts to unify contiguous slots of similar types to prevent boot failures.

Note: The necessity of this quirk is determined by early boot failures. It is rare to need this quirk on Haswell or newer. Do not use unless you fully understand the consequences.

13. `SignalAppleOS`
Type: `plist boolean`
Failsafe: `false`
Description: Report macOS being loaded through OS Info for any OS.

This quirk is useful on Mac firmwares, which behave differently in different OS. For example, it is supposed to enable Intel GPU in Windows and Linux in some dual-GPU MacBook models.

4. `MaxKernel`
   Type: `plist string`
   Failsafe: Empty string
   Description: Blocks kernel driver on specified macOS version or older.

   Note: Refer to `Add MaxKernel` description for matching logic.

5. `MinKernel`
   Type: `plist string`
   Failsafe: Empty string
   Description: Blocks kernel driver on specified macOS version or newer.

   Note: Refer to `Add MaxKernel` description for matching logic.

7.5 Emulate Properties

1. `Cpuid1Data`
   Type: `plist data`, 16 bytes
   Failsafe: All zero
   Description: Sequence of `EAX`, `EBX`, `ECX`, `EDX` values ~~in Little Endian order~~ to replace `CPUID (1)` call in XNU kernel.

   This property serves for two needs:

   - Enabling support of an unsupported CPU model.
   - Enabling XCPM support for an unsupported CPU variant.

   Normally it is only the value of `EAX` that needs to be taken care of, ~~which represents the exact CPUID. And the remainders~~ since it represents the full CPUID. The remaining bytes are to be left as zeroes. ~~For instance,~~ Byte order is Little Endian, so for example, `A9 06 03 00` stands for CPUID `0x0306A9` (Ivy Bridge). ~~A good example~~

   For XCPM support it is recommended to use the following combinations.

   - Haswell-E (`0x306F2`) to Haswell (`0x0306C3`):
     `Cpuid1Data: C3 06 03 00 00 00 00 00 00 00 00 00 00 00 00 00`
     `Cpuid1Mask: FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00`
   - Broadwell-E (`0x0406F1`) to Broadwell (`0x0306D4`):
     `Cpuid1Data: D4 06 03 00 00 00 00 00 00 00 00 00 00 00 00 00`
     `Cpuid1Mask: FF FF FF FF 00 00 00 00 00 00 00 00 00 00 00 00`

   Further explanations can be found at acidanthera/bugtracker#365. ~~(See~~ See `Special NOTES` ~~for Haswell~~ for Haswell+ low-end~~)~~.

2. `Cpuid1Mask`
   Type: `plist data`, 16 bytes
   Failsafe: All zero
   Description: Bit mask of active bits in `Cpuid1Data`.

   When each `Cpuid1Mask` bit is set to 0, the original CPU bit is used, otherwise set bits take the value of `Cpuid1Data`.

7.6 Patch Properties

1. `Base`
   Type: `plist string`
   Failsafe: Empty string
   Description: Selects symbol-matched base for patch lookup (or immediate replacement) by obtaining the address of provided symbol name. Can be set to empty string to be ignored.

2. `Comment`
   Type: `plist string`
   Failsafe: Empty string
   Description: Arbitrary ASCII string used to provide human readable reference for the entry. It is implementation defined whether this value is used.

7.7 Quirks Properties

1. `AppleCpuPmCfgLock`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Disables `PKG_CST_CONFIG_CONTROL` (`0xE2`) MSR modification in AppleIntelCPUPowerManagement.kext, commonly causing early kernel panic, when it is locked from writing.

   Note: This option should be avoided whenever possible. Modern firmwares provide `CFG Lock` setting, disabling which is much cleaner. More details about the issue can be found in VerifyMsrE2 notes.

2. `AppleXcpmCfgLock`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Disables `PKG_CST_CONFIG_CONTROL` (`0xE2`) MSR modification in XNU kernel, commonly causing early kernel panic, when it is locked from writing (XCPM power management).

   Note: This option should be avoided whenever possible. Modern firmwares provide `CFG Lock` setting, disabling which is much cleaner. More details about the issue can be found in VerifyMsrE2 notes.

3. `AppleXcpmExtraMsrs`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Disables multiple MSR access critical for select CPUs, which have no native XCPM support.

   This is normally used in conjunction with `Emulate` section on Haswell-E, Broadwell-E, Skylake-X, and similar CPUs. More details on the XCPM patches are outlined in acidanthera/bugtracker#365.

   Note: Additional not provided patches will be required for Ivy Bridge or Pentium CPUs. It is recommended to use `AppleIntelCpuPowerManagement.kext` for the former.

4. `AppleXcpmForceBoost`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Forces maximum performance in XCPM mode.

   This patch writes `0xFF00` to `MSR_IA32_PERF_CONTROL` (`0x199`), effectively setting maximum multiplier for all the time.

   Note: While this may increase the performance, this patch is strongly discouraged on all systems but those explicitly dedicated to scientific or media calculations. In general only certain Xeon models benefit from the patch.

5. `CustomSMBIOSGuid`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Performs GUID patching for `UpdateSMBIOSMode Custom` mode. Usually relevant for Dell laptops.

6. `DisableIoMapper`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Disables `IOMapper` support in XNU (VT-d), which may conflict with the firmware implementation.

   Note: This option is a preferred alternative to dropping `DMAR` ACPI table and disabling VT-d in firmware preferences, which does not break VT-d support in other systems in case they need it.

7. `ExternalDiskIcons`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Apply icon type patches to AppleAHCIPort.kext to force internal disk icons for all AHCI disks.

   Note: This option should be avoided whenever possible. Modern firmwares usually have compatible AHCI controllers.

- `CMD+S` — single user mode.
- `CMD+S+MINUS` — disable KASLR slide, requires disabled SIP.
- `CMD+V` — verbose mode.
- `Shift` — safe mode.

7. `Resolution`
   Type: `plist string`
   Failsafe: Empty string
   Description: Sets console output screen resolution.

   - Set to `WxH@Bpp` (e.g. `1920x1080@32`) or `WxH` (e.g. `1920x1080`) formatted string to request custom resolution from GOP if available.
   - Set to empty string not to change screen resolution.
   - Set to `Max` to try to use largest available screen resolution.

   On HiDPI screens `APPLE_VENDOR_VARIABLE_GUID` `UIScale` NVRAM variable may need to be set to `02` to enable HiDPI scaling in FileVault 2 UEFI password interface and boot screen logo. Refer to Recommended Variables section for more details.

   Note: This will fail when console handle has no GOP protocol. When the firmware does not provide it, it can be added with `ProvideConsoleGop` UEFI quirk set to `true`.

8. `ShowPicker`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Show simple boot picker to allow boot entry selection.

9. `Timeout`
   Type: `plist integer`, 32 bit
   Failsafe: `0`
   Description: Timeout in seconds in boot picker before automatic booting of the default boot entry. Use 0 to disable timer.

10. `UsePicker`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Use OpenCore built-in boot picker for boot management.

    `UsePicker` set to `false` entirely disables all boot management in OpenCore except policy enforcement. In this case a custom user interface may utilise OcSupportPkg `OcBootManagementLib` to implement a user friendly boot picker oneself. Reference example of external graphics interface is provided in ExternalUi test driver.

    OpenCore built-in boot picker contains a set of actions chosen during the boot process. The list of supported actions is similar to Apple BDS and currently consists of the following options:

    - `Default` — this is the default option, and it lets OpenCore built-in boot picker to loads the default boot option as specified in Startup Disk preference pane.
    - `ShowPicker` — this option forces picker to show. Normally it can be achieved by holding `OPT` key during boot. Setting `ShowPicker` to `true` will make `ShowPicker` the default option.
    - `ResetNvram` — this option performs select UEFI variable erase and is normally achieved by holding `CMD+OPT+P+R` key combination during boot. Another way to erase UEFI variables is to choose `Reset NVRAM` in the picker. This option requires `AllowNvramReset` to be set to `true`.
    - `BootApple` — this options performs booting to the first found Apple operating system unless the default chosen operating system is already made by Apple. Hold `X` key to choose this option.
    - `BootAppleRecovery` — this option performs booting to Apple operating system recovery. Either the one related to the default chosen operating system, or first found in case default chosen operating system is not made by Apple or has no recovery. Hold `CMD+R` key combination to choose this option.

    Note: activated `KeySupport`, ~~`UsbKbDxe`~~`AppleUsbKbDxe`, or similar driver is required for key handling to work. On many firmwares it is not possible to get all the keys function.

    In addition to `OPT` OpenCore supports `Escape` key `ShowPicker`. This key exists for firmwares with PS/2 keyboards that fail to report held `OPT` key and require continual presses of `Escape` key to enter the boot menu.

File logging will create a file named `opencore-YYYY-MM-DD-HHMMSS.txt` at EFI volume root with log contents (the upper case letter sequence is replaced with date and time from the firmware). Please be warned that some file system drivers present in firmwares are not reliable, and may corrupt data when writing files through UEFI. Log is attempted to be written in the safest manner, and thus is very slow. Ensure that `DisableWatchDog` is set to `true` when you use a slow drive.

8.5 Security Properties

1. `AllowNvramReset`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Allow `CMD+OPT+P+R` handling and enable showing `NVRAM Reset` entry in boot picker.

2. `AllowSetDefault`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Allow `CTRL+Enter` and `CTRL+Index` handling to set the default boot option in boot picker.

3. `AuthRestart`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Enable `VirtualSMC`-compatible authenticated restart.

   Authenticated restart is a way to reboot FileVault 2 enabled macOS without entering the password. To perform authenticated restart one can use a dedicated terminal command: `sudo fdesetup authrestart`. It is also used when installing operating system updates.

   VirtualSMC performs authenticated restart by saving disk encryption key split in NVRAM and RTC, which despite being removed as soon as OpenCore starts, may be considered a security risk and thus is optional.

4. `ExposeSensitiveData`
   Type: `plist integer`
   Failsafe: `0x6`
   Description: Sensitive data exposure bitmask (sum) to operating system.

   - `0x01` — Expose printable booter path as an UEFI variable.
   - `0x02` — Expose OpenCore version as an UEFI variable.
   - `0x04` — Expose OpenCore version in boot picker menu title.

   Exposed booter path points to OpenCore.efi or its booter depending on the load order. To obtain booter path use the following command in macOS:

   ```
   nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:boot-path
   ```

   To use booter path for mounting booter volume use the following command in macOS:

   ```
   u=$(nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:boot-path | sed 's/.*GPT,\([^,]*\),.*/\1/'); \
     if [ "$u" != "" ]; then sudo diskutil mount $u ; fi
   ```

   To obtain OpenCore version use the following command in macOS:

   ```
   nvram 4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102:opencore-version
   ```

5. `HaltLevel`
   Type: `plist integer`, 64 bit
   Failsafe: `0x80000000` (`DEBUG_ERROR`)
   Description: EDK II debug level bitmask (sum) causing CPU to halt (stop execution) after obtaining a message of `HaltLevel`. Possible values match `DisplayLevel` values.

6. `RequireSignature`
   Type: `plist boolean`
   Failsafe: `true`
   Description: Require `vault.sig` signature file for `vault.plist` in `OC` directory.

9 NVRAM

9.1 Introduction

Has `plist dict` type and allows to set volatile UEFI variables commonly referred as NVRAM variables. Refer to `man nvram` for more details. macOS extensively uses NVRAM variables for OS — Bootloader — Firmware intercommunication, and thus supplying several NVRAM is required for proper macOS functioning.

Each NVRAM variable consists of its name, value, attributes (refer to UEFI specification), and its GUID, representing which 'section' NVRAM variable belongs to. macOS uses several GUIDs, including but not limited to:

- `4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14` (`APPLE_VENDOR_VARIABLE_GUID`)
- `7C436110-AB2A-4BBB-A880-FE41995C9F82` (`APPLE_BOOT_VARIABLE_GUID`)
- `8BE4DF61-93CA-11D2-AA0D-00E098032B8C` (`EFI_GLOBAL_VARIABLE_GUID`)
- `4D1FDA02-38C7-4A6A-9CC6-4BCCA8B30102` (`OC_VENDOR_VARIABLE_GUID`)

Note: Some of the variables may be added by PlatformNVRAM or Generic subsections of PlatformInfo section. Please ensure that variables of this section never collide with them, as behaviour is undefined otherwise.

For proper macOS functioning it is often required to use `OC_FIRMWARE_RUNTIME` protocol implementation currently offered as a part of `FwRuntimeServices` driver. While it brings any benefits, there are certain limitations which arise depending on the use.

1. Not all tools may be aware of protected namespaces.
   When `RequestBootVarRouting` is used `Boot`-prefixed variable access is restricted and protected in a separate namespace. To access the original variables tools have to be aware of `OC_FIRMWARE_RUNTIME` logic.
2. Assigned NVRAM variables are not always allowed to exceed 512 bytes.
   This is true for `Boot`-prefixed variables when `RequestBootVarFallback` is used, and for overwriting volatile variables with non-volatile on UEFI 2.8 non-conformant firmwares.

9.2 Properties

1. `Add`
   Type: `plist dict`
   Description: Sets NVRAM variables from a map (`plist dict`) of GUIDs to a map (`plist dict`) of variable names and their values in `plist metadata` format. GUIDs must be provided in canonic string format in upper or lower case (e.g. `8BE4DF61-93CA-11D2-AA0D-00E098032B8C`).

   Created variables get `EFI_VARIABLE_BOOTSERVICE_ACCESS` and `EFI_VARIABLE_RUNTIME_ACCESS` attributes set. Variables will only be set if not present and not blocked. To overwrite a variable add it to `Block` section. This approach enables to provide default values till the operating system takes the lead.

   Note: If `plist key` does not conform to GUID format, behaviour is undefined.

2. `Block`
   Type: `plist dict`
   Description: Removes NVRAM variables from a map (`plist dict`) of GUIDs to an array (`plist array`) of variable names in `plist string` format.

3. `LegacyEnable`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Enables loading of NVRAM variable file named `nvram.plist` from EFI volume root.

   This file must have root `plist dictionary` type and contain two fields:

   - `Version` — `plist integer`, file version, must be set to 1.
   - `Add` — `plist dictionary`, equivalent to `Add` from `config.plist`.

   Variable loading happens prior to `Block` (and `Add`) phases~~, and~~. Unless `LegacyOverwrite` is enabled, it will not overwrite any existing variable. Variables allowed to be set must be specified in `LegacySchema`. Third-party scripts may be used to create `nvram.plist` file. An example of such script can be found in `Utilities`. The use of

third-party scripts may require `ExposeSensitiveData` set to `0x3` to provide `boot-path` variable with OpenCore EFI partition UUID.

WARNING: This feature is very dangerous as it passes unprotected data to your firmware variable services. Use it only when no hardware NVRAM implementation is provided by the firmware or it is incompatible.

4. `LegacyOverwrite`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Permits overwriting firmware variables from `nvram.plist`.

   Note: Only variables accessible from the operating system will be overwritten.

5. `LegacySchema`
   Type: `plist dict`
   Description: Allows setting select NVRAM variables from a map (`plist dict`) of GUIDs to an array (`plist array`) of variable names in `plist string` format.

   You can use `*` value to accept all variables for select GUID.

   WARNING: Choose variables very carefully, as nvram.plist is not vaulted. For instance, do not put `boot-args` or `csr-active-config`, as this can bypass SIP.

6. `WriteFlash`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Enables writing to flash memory for all added variables.

   Note: This value is recommended to be enabled on most firmwares, but is left configurable for firmwares that may have issues with NVRAM variable storage garbage collection or alike.

To read NVRAM variable value from macOS one could use `nvram` by concatenating variable GUID and name separated by `:` symbol. For example, `nvram 7C436110-AB2A-4BBB-A880-FE41995C9F82:boot-args`.

A continuously updated variable list can be found in a corresponding document: NVRAM Variables.

9.3 Mandatory Variables

Warning: These variables may be added by PlatformNVRAM or Generic subsections of PlatformInfo section. Using `PlatformInfo` is the recommend way of setting these variables.

The following variables are mandatory for macOS functioning:

- `4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeatures`
  32-bit `FirmwareFeatures`. Present on all Macs to avoid extra parsing of SMBIOS tables
- `4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:FirmwareFeaturesMask`
  32-bit `FirmwareFeaturesMask`. Present on all Macs to avoid extra parsing of SMBIOS tables.
- `4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:MLB`
  `BoardSerialNumber`. Present on newer Macs (2013+ at least) to avoid extra parsing of SMBIOS tables, especially in boot.efi.
- `4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ROM`
  Primary network adapter MAC address or replacement value. Present on newer Macs (2013+ at least) to avoid accessing special memory region, especially in boot.efi.

9.4 Recommended Variables

The following variables are recommended for faster startup or other improvements:

- `7C436110-AB2A-4BBB-A880-FE41995C9F82:csr-active-config`
  32-bit System Integrity Protection bitmask. Declared in XNU source code in csr.h.
- `4D1EDE05-38C7-4A6A-9CC6-4BCCA8B38C14:ExtendedFirmwareFeatures`
  Combined `FirmwareFeatures` and `ExtendedFirmwareFeatures`. Present on newer Macs to avoid extra parsing of SMBIOS tables

- `Overwrite` — Overwrite existing gEfiSmbiosTableGuid and gEfiSmbiosTable3Guid data if it fits new size. Abort with unspecified state otherwise.
- `Custom` — Write first SMBIOS table (`gEfiSmbiosTableGuid`) to `gOcCustomSmbiosTableGuid` to workaround firmwares overwriting SMBIOS contents at ExitBootServices. Otherwise equivalent to `Create`. Requires patching AppleSmbios.kext and AppleACPIPlatform.kext to read from another GUID: `"EB9D2D31"` - `"EB9D2D35"` (in ASCII), done automatically by `CustomSMBIOSGuid` quirk.

6. `Generic`
   Type: `plist dictonary`
   Optional: When `Automatic` is `false`
   Description: Update all fields. This section is read only when `Automatic` is active.

7. `DataHub`
   Type: `plist dictonary`
   Optional: When `Automatic` is `true`
   Description: Update Data Hub fields. This section is read only when `Automatic` is not active.

8. `PlatformNVRAM`
   Type: `plist dictonary`
   Optional: When `Automatic` is `true`
   Description: Update platform NVRAM fields. This section is read only when `Automatic` is not active.

9. `SMBIOS`
   Type: `plist dictonary`
   Optional: When `Automatic` is `true`
   Description: Update SMBIOS fields. This section is read only when `Automatic` is not active.

10.2 Generic Properties

1. `SpoofVendor`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Sets SMBIOS vendor fields to `Acidanthera`.

   It is dangerous to use Apple in SMBIOS vendor fields for reasons given in `SystemManufacturer` description. However, certain firmwares may not provide valid values otherwise, which could break some software.

2. `SupportsCsm`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Forces CSM support in `FirmwareFeatures`.

   Without this bit it is not possible to reboot to Windows installed on a drive with EFI partition being not the first partition on the disk.

   Note: This was enabled unconditionally in older OpenCore versions.

3. `SystemProductName`
   Type: `plist string`
   Failsafe: `MacPro6,1`
   Description: Refer to SMBIOS `SystemProductName`.

4. `SystemSerialNumber`
   Type: `plist string`
   Failsafe: `OPENCORE_SN1`
   Description: Refer to SMBIOS `SystemSerialNumber`.

5. `SystemUUID`
   Type: `plist string`, GUID
   Failsafe: OEM specified
   Description: Refer to SMBIOS `SystemUUID`.

6. `MLB`
   Type: `plist string`

11 UEFI

11.1 Introduction

UEFI (Unified Extensible Firmware Interface) is a specification that defines a software interface between an operating system and platform firmware. This section allows to load additional UEFI modules and/or apply tweaks for the onboard firmware. To inspect firmware contents, apply modifications and perform upgrades UEFITool and supplementary utilities can be used.

11.2 Properties

1. `ConnectDrivers`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Perform UEFI controller connection after driver loading. This option is useful for loading filesystem drivers, which usually follow UEFI driver model, and may not start by themselves. While effective, this option ~~is not necessary with e.g. APFS loader driver~~may not be necessary for drivers performing automatic connection, and may slightly slowdown the boot.

2. `Drivers`
   Type: `plist array`
   Failsafe: None
   Description: Load selected drivers from `OC/Drivers` directory.

   Designed to be filled with string filenames meant to be loaded as UEFI drivers. Depending on the firmware a different set of drivers may be required. Loading an incompatible driver may lead your system to unbootable state or even cause permanent firmware damage. Some of the known drivers include:

   - `ApfsDriverLoader` — APFS file system bootstrap driver adding the support of embedded APFS drivers in bootable APFS containers in UEFI firmwares.
   - `FwRuntimeServices` — `OC_FIRMWARE_RUNTIME` protocol implementation that increases the security of OpenCore and Lilu by supporting read-only and write-only NVRAM variables. Some quirks, like `RequestBootVarRouting`, require this driver for proper function. Due to the nature of being a runtime driver, i.e. functioning in parallel with the target operating system, it cannot be implemented within OpenCore itself, but is bundled with OpenCore releases.
   - `EnhancedFatDxe` — FAT filesystem driver from `FatPkg`. This driver is embedded in all UEFI firmwares, and cannot be used from OpenCore. It is known that multiple firmwares have a bug in their FAT support implementation, which leads to corrupted filesystems on write attempt. Embedding this driver within the firmware may be required in case writing to EFI partition is needed during the boot process.
   - `NvmExpressDxe` — NVMe support driver from `MdeModulePkg`. This driver is included in most firmwares starting with Broadwell generation. For Haswell and earlier embedding it within the firmware may be more favourable in case a NVMe SSD drive is installed.
   - `AppleUsbKbDxe` — USB keyboard driver adding the support of `AppleKeyMapAggregator` protocols on top of a custom USB keyboard driver implementation. This is an alternative to builtin `KeySupport`, which may work better or worse depending on the firmware.
   - ~~— UEFI SMC driver, required for proper FileVault 2 functionality and potentially other macOS specifics. An alternative, named `SMCHelper`, is not compatible with `VirtualSmc` and OpenCore, which is unaware of its specific interfaces. In case `FakeSMC` kernel extension is used, manual NVRAM variable addition may be needed and `VirtualSmc` driver should still be used.~~
   - `VBoxHfs` — HFS file system driver with bless support. This driver is an alternative to a closed source `HFSPlus` driver commonly found in Apple firmwares. While it is feature complete, it is approximately 3 times slower and is yet to undergo a security audit.
   - `XhciDxe` — XHCI USB controller support driver from `MdeModulePkg`. This driver is included in most firmwares starting with Sandy Bridge generation. For earlier firmwares or legacy systems it may be used to support external USB 3.0 PCI cards.

   To compile the drivers from UDK (EDK II) use the same command you do normally use for OpenCore compilation, but choose a corresponding package:

```
git clone https://github.com/acidanthera/audk UDK
```

```
cd UDK
source edksetup.sh
make -C BaseTools
build -a X64 -b RELEASE -t XCODE5 -p FatPkg/FatPkg.dsc
build -a X64 -b RELEASE -t XCODE5 -p MdeModulePkg/MdeModulePkg.dsc
```

3. `Input`
   Type: `plist dict`
   Failsafe: None
   Description: Apply individual settings designed for input (keyboard and mouse) in Input Properties section below.

4. `Protocols`
   Type: `plist dict`
   Failsafe: None
   Description: Force builtin versions of select protocols described in Protocols Properties section below.

   Note: all protocol instances are installed prior to driver loading.

5. `Quirks`
   Type: `plist dict`
   Failsafe: None
   Description: Apply individual firmware quirks described in Quirks Properties section below.

11.3 Input Properties

1. `KeyForgetThreshold`
   Type: `plist integer`
   Failsafe: `0`
   Description: Remove key unless it was submitted during this timeout in milliseconds.

   `AppleKeyMapAggregator` protocol is supposed to contain a fixed length buffer of currently pressed keys. However, the majority of the drivers only report key presses as interrupts and pressing and holding the key on the keyboard results in subsequent submissions of this key with some defined time interval. As a result we use a timeout to remove once pressed keys from the buffer once the timeout expires and no new submission of this key happened.

   This option allows to set this timeout based on your platform. The recommended value that works on the majority of the platforms is `5` milliseconds. For reference, holding one key on VMware will repeat it roughly every `2` milliseconds and the same value for APTIO V is `3-4` milliseconds. Thus it is possible to set a slightly lower value on faster platforms and slightly higher value on slower platforms for more responsive input.

2. `KeyMergeThreshold`
   Type: `plist integer`
   Failsafe: `0`
   Description: Assume simultaneous combination for keys submitted within this timeout in milliseconds.

   Similarly to `KeyForgetThreshold`, this option works around the sequential nature of key submission. To be able to recognise simultaneously pressed keys in the situation when all keys arrive sequentially, we are required to set a timeout within which we assume the keys were pressed together.

   Holding multiple keys results in reports every `2` and `1` milliseconds for VMware and APTIO V respectively. Pressing keys one after the other results in delays of at least `6` and `10` milliseconds for the same platforms. The recommended value for this option is `2` milliseconds, but it may be decreased for faster platforms and increased for slower.

3. `KeySupport`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Enable internal keyboard input translation to `AppleKeyMapAggregator` protocol.

   This option activates the internal keyboard interceptor driver, based on `AppleGenericInput` aka (`AptioIntputFix`), to fill `AppleKeyMapAggregator` database for input functioning. In case a separate driver is used, such as ~~`UsbKbDxe`~~`AppleUsbKbDxe`, this option should never be enabled.

4. `AppleKeyMap`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Apple Key Map protocols with builtin versions.

5. `AppleSmcIo`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Apple SMC I/O protocol with a builtin version.

   This protocol replaces legacy `VirtualSmc` UEFI driver, and is compatible with any SMC kernel extension. However, in case `FakeSMC` kernel extension is used, manual NVRAM key variable addition may be needed.

6. `AppleUserInterfaceTheme`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Apple User Interface Theme protocol with a builtin version.

7. `ConsoleControl`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Replaces Console Control protocol with a builtin version.

   macOS bootloader requires console control protocol for text output, which some firmwares miss. This option is required to be set when the protocol is already available in the firmware, and other console control options are used, such as `IgnoreTextInGraphics`, `SanitiseClearScreen`, and sometimes `ConsoleBehaviourOs` with `ConsoleBehaviourUi`).

8. `DataHub`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Data Hub protocol with a builtin version. This will drop all previous properties if the protocol was already installed.

9. `DeviceProperties`
   Type: `plist boolean`
   Failsafe: `false`
   Description: Reinstalls Device Property protocol with a builtin version. This will drop all previous properties if it was already installed. This may be used to ensure full compatibility on VMs or legacy Macs.

10. `FirmwareVolume`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Forcibly wraps Firmware Volume protocols or installs new to support custom cursor images for File Vault 2. Should be set to `true` to ensure File Vault 2 compatibility on everything but VMs and legacy Macs.

11. `HashServices`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Forcibly reinstalls Hash Services protocols with builtin versions. Should be set to `true` to ensure File Vault 2 compatibility on platforms providing broken SHA-1 hashing. Can be diagnosed by invalid cursor size with `UIScale` set to `02`, in general platforms prior to APTIO V (Haswell and older) are affected.

12. `OSInfo`
    Type: `plist boolean`
    Failsafe: `false`
    Description: Forcibly reinstalls OS Info protocol with builtin versions. This protocol is generally used to receive notifications from macOS bootloader, by the firmware or by other applications.

13. `UnicodeCollation`
    Type: `plist boolean`
    Failsafe: `false`